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13. ABSTRACT *(Maximum 200 words)*

THE PURPOSE OF THIS STUDY WAS TO DEVELOP BENCH AND PILOT SCALE ADSORPTION DATA ON SELECTED GRADES OF COAL-BASE GRANULAR ACTIVATED CARBON (GAC) TO IDENTIFY AND SELECT SOURCES OF GAC FOR COMPETITIVE PROCUREMENT FOR THE RMA NORTH BOUNDARY TREATMENT PROJECT. A TEST PLAN SETTING FORTH EACH PHASE OF THE WORK TO BE PERFORMED WAS PREPARED AND SUBMITTED TO RMA ON SEPTEMBER 30, 1980. ITEMS IDENTIFIED FOR STUDY DURING THE FIRST PHASE (TASK 1-ALTERNATE CARBON SOURCE STUDY) INCLUDE SELECTING CARBONS FOR EVALUATION, DEVELOPING ADSORPTION ISOTHERMS FOR THOSE CARBONS AND OBTAINING DYNAMIC ADSORPTION DATA IN PILOT SCALE CARBON COLUMNS. THE TEST WORK WAS TO BE PERFORMED BY R/H AT RMA FACILITIES WITH ASSISTANCE FROM AND CHEMICAL ANALYSIS PROVIDED BY RMA. AN INTERIM REPORT SUMMARIZING THE RESULTS OF PRELIMINARY CARBON SOURCE SCREENING EFFORTS, ADSORPTION ISOTHERM TESTING AND RESULTS OF LABORATORY REACTIVATION OF FOUR SAMPLES OF SPENT GRANULAR ACTIVATED CARBON WAS SUBMITTED TO RMA ON JAN. 10, 1981. THIS REPORT INCLUDES THE RESULTS OF ALL STUDIES CONDUCTED UNDER TASK 1 OF

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REPORT

ALTERNATIVE CARBON SOURCE STUDY

FOR

THE DEPARTMENT OF THE ARMY

ROCKY MOUNTAIN ARSENAL

(REF. CONTRACT #DAAA05-80-R-0016)

by

RUBEL AND HAGER, INC.

4400 East Broadway

Tucson, Arizona

June 15, 1981

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INTRODUCTION

The purpose of this study was to develop bench and pilot scale adsorption data on selected grades of coal based granular activated carbon (GAC) to identify and select sources of GAC for competitive procurement for the Rocky Mountain Arsenal (RMA) North Boundary Treatment Project. A test plan setting forth each phase of the work to be performed was prepared and submitted to RMA on September 30, 1980. Items identified for study during the first phase (Task 1-Alternate Carbon Source Study) included selecting carbons for evaluation, developing adsorption isotherms for those carbons and obtaining dynamic adsorption data in pilot scale carbon columns. The test work was to be performed by R/H at RMA facilities with assistance from and chemical analyses provided by RMA. An Interim Report summarizing the results of preliminary carbon source screening efforts, adsorption isotherm testing and results of laboratory reactivation of four samples of spent granular activated carbon was submitted to RMA on January 30, 1981. This Report includes the results of all studies conducted under Task 1 of the project. Based on the results presented herein, a GAC product will be selected from those tested for Task 2-Activated Carbon Pilot Plant Adsorption and Reactivation Studies.

SELECTION OF GAC PRODUCTS FOR TESTING

The manufacturers of GAC in the United States are:

Manufacturer (and Parent Company)	GAC Production Capacity (million #/Yr.)	Raw Material
° Barneby Cheney (Pennwalt)	3	Miscellaneous
° Calgon	60	Coal
° Carborundum (Kennecott)	20	Coal
° ICI - US (Imperial Chemical Industries)	40	Lignite
° Pacific Carbon	3	Wood
° Union Carbide	8	Acid Sludge Coke
° Westvaco	30	Coal or Wood
° Witco	3	Acid Sludge Coke

The intended use of GAC at the RMA north boundary and other future locations is to utilize counter-current adsorption systems with hydraulic transport between adsorbers and storage area. Also there is a potential future requirement of thermal reactivation.

The GAC to be tested in this program should possess sufficient physical strength and the proper particle size to exhibit low head loss in the adsorbers and to withstand hydraulic transport procedures. Experience in industrial facilities indicate that coal, coconut and acid sludge coke based carbons possess a structural strength which provides a minimum loss of carbon due to attrition in handling. Of these, the coconut and acid sludge coke based materials are typically used in vapor phase applications and carry a higher price.

Coal based carbons offer both low price and good physical strength. Westvaco, Calgon and Carborundum offer various grades of coal based GAC. A 12x40 mesh particle size GAC matches RMA adsorber requirements.

Those products which were selected for testing are:

Westvaco WV-L

Calgon FS-400

Carborundum GAC 40

Copies of Specification Sheets on these products can be found in Appendix A.

ADOSRPTION ISOTHERM TESTING

A. Experimental Objectives

The objectives of developing activated carbon adsorption isotherm data for the north boundary ground water were to determine the relative adsorption capacities of the tested carbons for the organic materials in the water, compare the degree to which each material is removed and to determine whether the adsorption of the material is enhanced by adsorbing at a higher or lower pH of water.

B. Experimental Procedures

1. Ground Water pH Adjustment. A sample of untreated ground water at pH 7.8 was obtained at the north boundary well water sump for use in developing a pH titration curve. A 500 ml sample was stirred and sulfuric acid or sodium hydroxide solutions (0.5%) were added dropwise. Sulfuric acid was added to the first sample and the amounts required to bring the pH to 7.0, 6.0, 5.0 and 4.0 were recorded. The sample was then titrated back to the original value by adding 0.5% NaOH. The required amounts were recorded to pH 5.0, 6.0, 7.0 and 7.8.

Caustic soda was added to a second 500 ml sample and the quantity required to obtain pH 8.0, 9.0 and 10 was recorded.

The resulting acid and caustic soda titration curves are shown in Figures 1 and 2.

2. Adsorption Isotherm Tests. The three granular activated carbons selected from the screening process were pulverized in accordance with standard procedures as described in Appendix B. Water for the tests was collected at the north boundary barrier system untreated water sump. Prior to starting the tests, the water was filtered through glass fiber filters. Five gallon volumes of water were used for pH adjustment to provide enough water for all carbons at each pH value. The isotherms were run at pH 7.8 (unmodified), 9, 6 and 4.

A weighed quantity of pulverized carbon and 800 ml of water were placed in each of seven one-liter flasks and fastened to a Burrell wrist action shaker. An eighth flask containing water but no carbon was also attached to the shaker as a "blank". The flasks were then agitated for three hours. After agitation, the liquid was filtered through glass fiber filters and delivered to the laboratory for analysis.

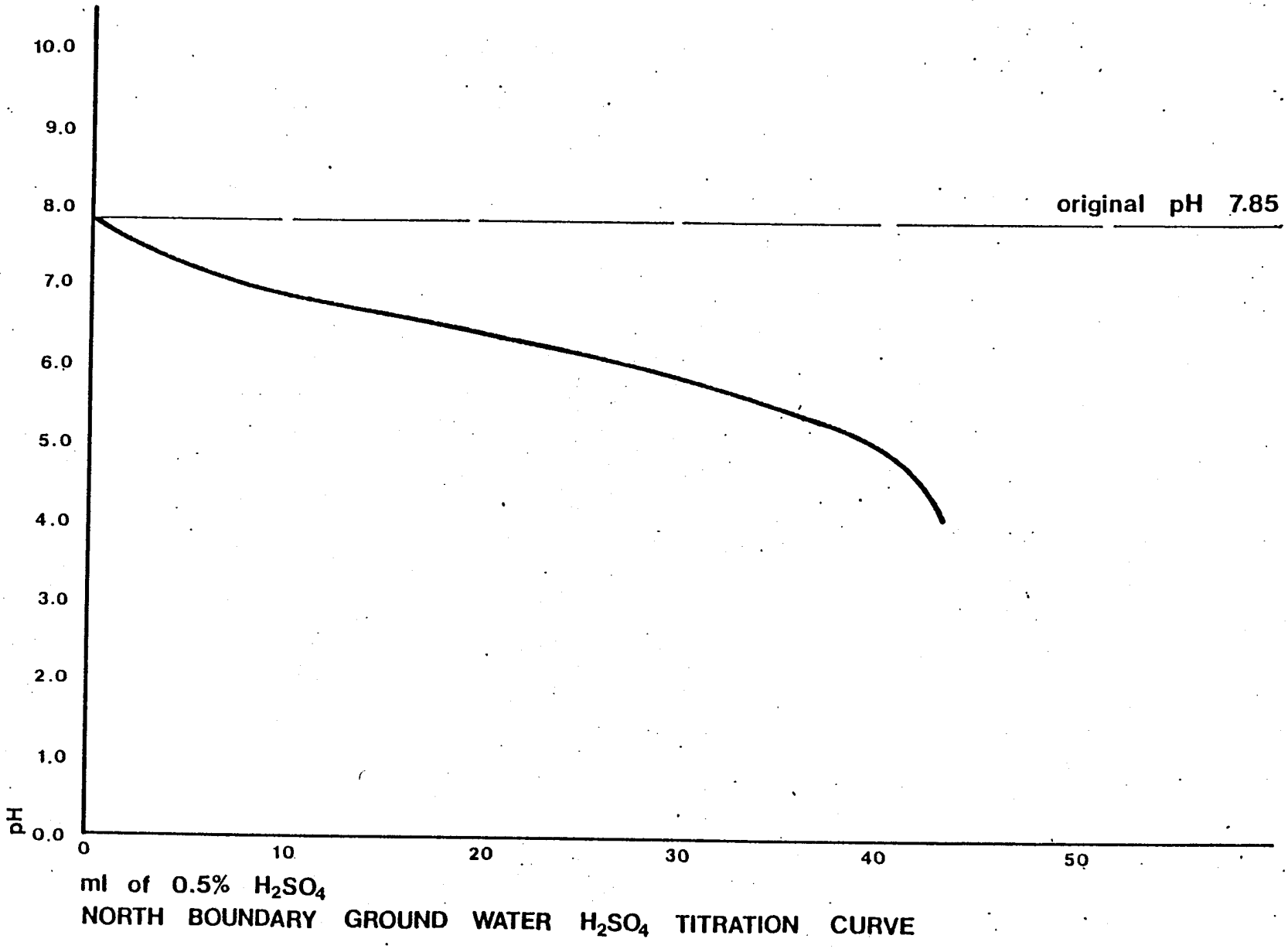
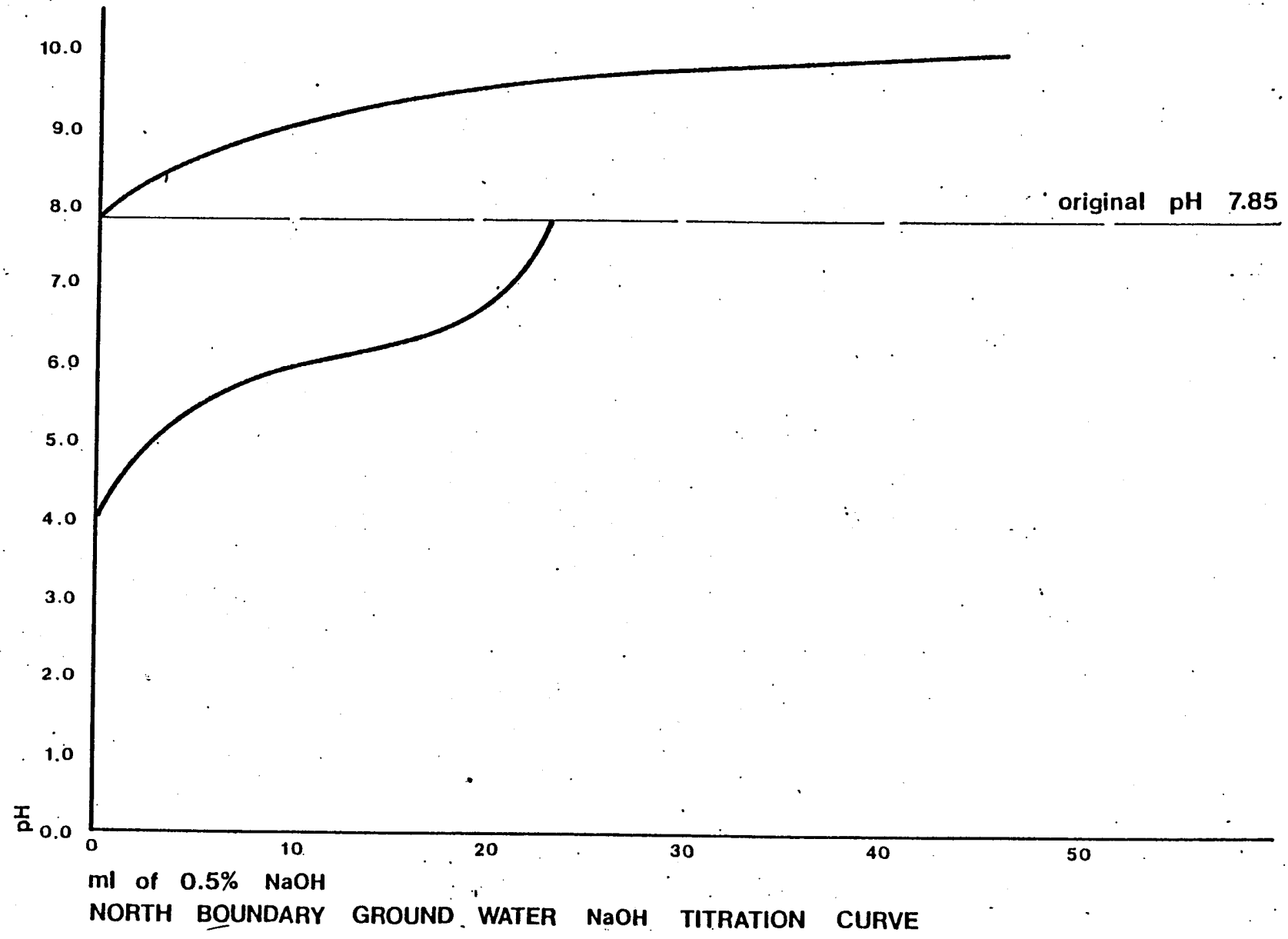

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
pH
original pH 7.85
0
10
20
30
40
50
ml of 0.5% H_2SO_4
NORTH BOUNDARY GROUND WATER H_2SO_4 TITRATION CURVE

FIGURE 1



NORTH BOUNDARY GROUND WATER NaOH TITRATION CURVE

FIGURE 2

C. Experimental Results

Analytical data resulting from the first isotherm test samples were unsuitable for calculating the isotherm curves. The test work was repeated after the analytical procedures and equipment were examined and improved.

The raw analytical data resulting from the adsorption isotherm procedures are listed in Appendices C-1, C-2 and C-3 for Westvaco, Carborundum and Calgon carbons respectively. Those values for organic concentrations are reported on a manually calculated basis in Appendix C-3 and on a computer generated basis in Appendices C-1 and C-2. Computer generated data have μg/l minimum values of 10 μg/l DIMP, 0.20 μg/l DBCP and 20 μg/l DITH, OXAT, CPMSO, CPMO2, and PCPMS. Comparison of data for the three carbons below the minimum values are considered insignificant. The data are presented graphically in Figures 3, 4 and 5.

Seven organic compounds were analyzed and all but DIMP were removed with the lowest carbon dosage. This is consistent with previous north boundary water testing experience and the following observations are therefore based upon DIMP removal.

DIMP was removed most effectively at a pH of 9 and least effectively at a pH of 4 for all three carbons under evaluation. The slopes of the curves for Westvaco and Calgon carbons (Figures 3 and 5) are slightly greater than the Carborundum carbon (Figure 4) indicating a greater sensitivity to DIMP concentration.

The highest weight pickup at influent concentrations resulted with the Westvaco carbon at a pH of 9. The least weight pickup at influent concentration was exhibited by the Calgon material at a pH of 4.

The data clearly indicate that higher pH values result in greater affinity of DIMP for all three carbons. However, the difference in capacity at pH 9 compared to pH 7.8 (ambient) is not significant and pH adjustment costs are not justified.

Consequently all three carbons were tested in the pilot columns testing program using north boundary water at ambient pH.

FIGURE 3 - Adsorption Isotherm
Westvaco WV-L (pulverized)

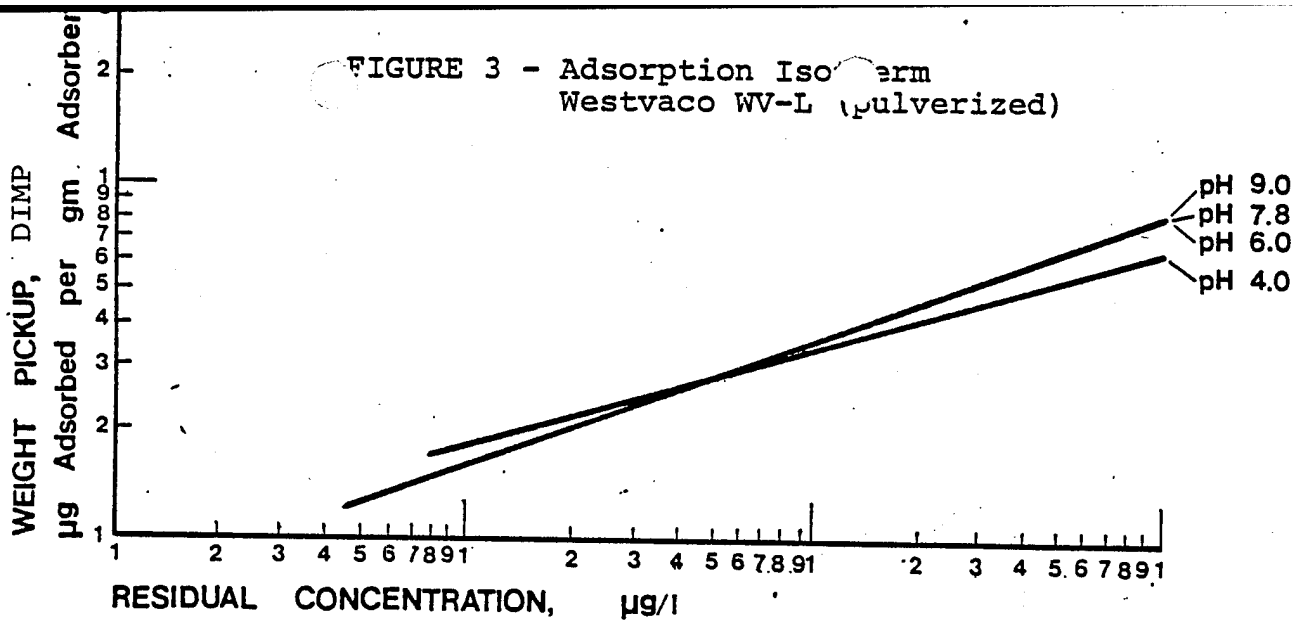


FIGURE 4 - Adsorption Isotherm
Carborundum GAC (pulverized)

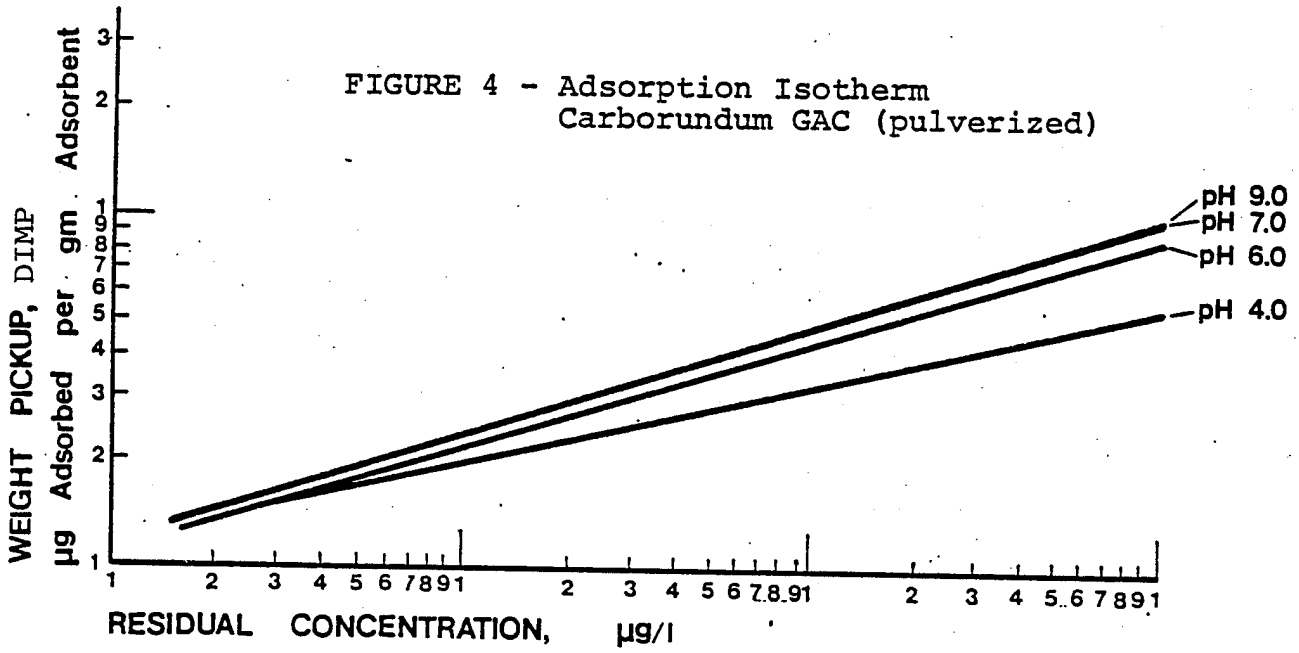
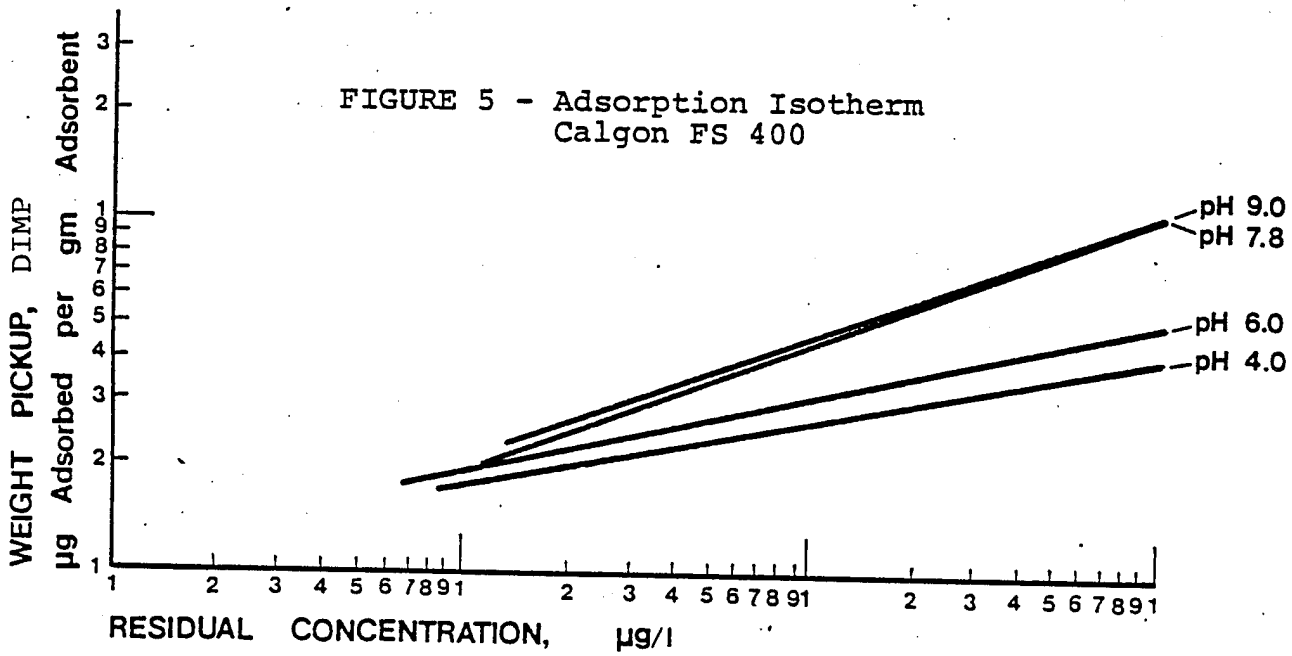


FIGURE 5 - Adsorption Isotherm
Calgon FS 400



GRANULAR ACTIVATED CARBON COLUMN STUDIES

A. Experimental Objectives

The objective of these studies was to compare the three carbons for DIMP removal from north boundary ground water under dynamic flow conditions. At various contact times, these data will establish carbon exhaustion rates (pounds used per gallon of water treated) and determine minimum contact time required to reach effluent quality objectives.

B. Experimental Equipment and Procedures

A flow diagram for the carbon column studies is shown in Figure 6. The flow rate was controlled at 0.27 gallons per minute to achieve 3.75 minutes contact time per foot of carbon bed depth (30 minutes total @ 8' depth). A valve was installed above the rotameter at the inlet to the lead column in each series to manually bleed off any air which may accumulate in the line. A sand filter was used to filter the ground water ahead of the pilot carbon columns to avoid filtering solids in the carbon columns which would interfere with the column operation and data gathering. A control column was operated without pre-filtration to evaluate the need for filtration in a full-scale treatment facility.

The column studies were initiated on January 15, 1981 and were continued until May 26 when it was confirmed that all the carbon was exhausted.

Water samples were collected three times per week (Monday, Wednesday and Friday) at the sand filter inlet, sand filter outlet, and the discharge from each carbon column. All samples were analyzed for TOC, pH, and DIMP. In addition, the samples collected each Friday were analyzed specifically for organic sulfur compounds, DCBP and pesticides. When the carbon in the first column of each series was exhausted, sampling of the effluent from that column was discontinued.

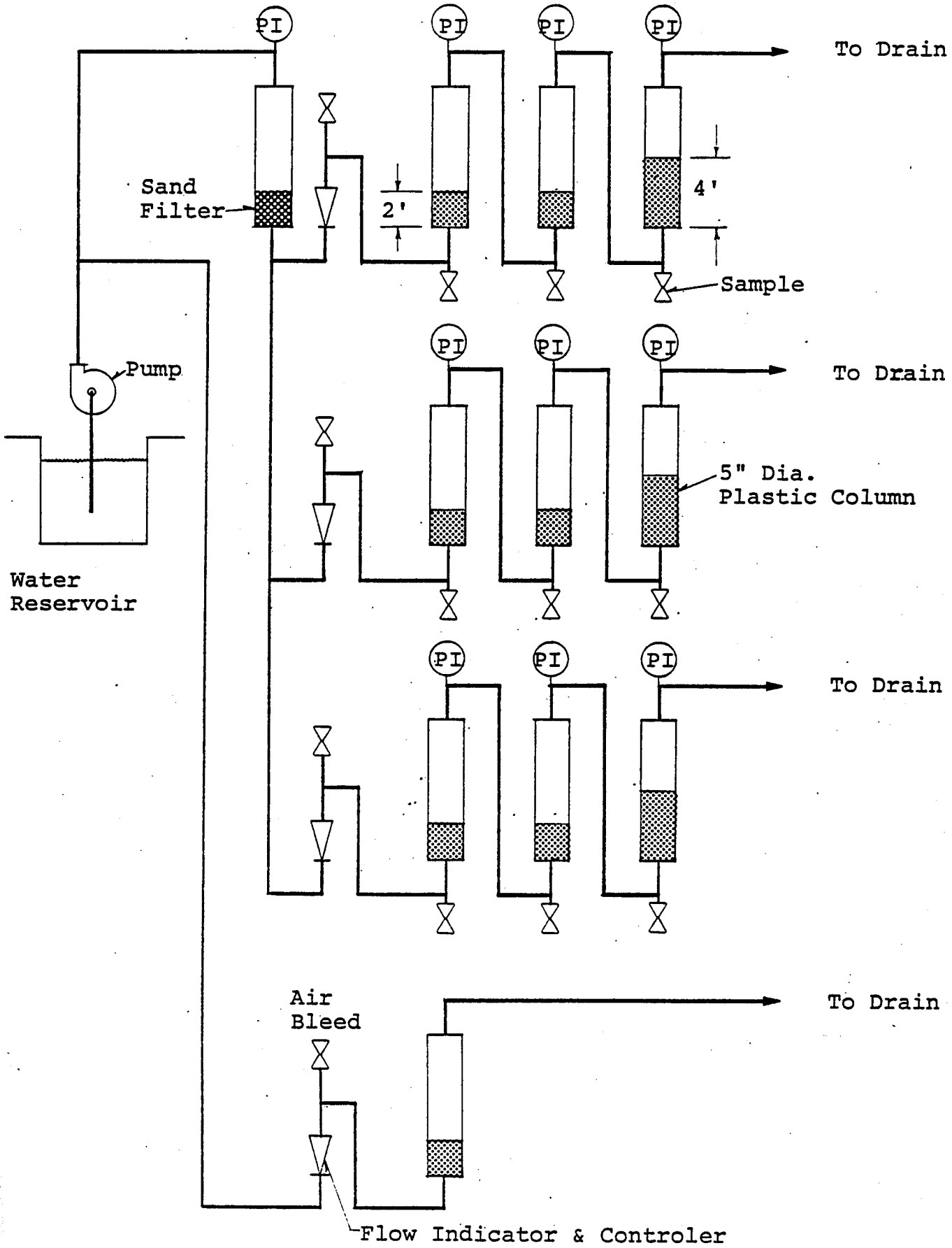
C. Experimental Results

All the data resulting from the GAC pilot studies are presented in Appendix D.

Untreated groundwater quality data is shown in Appendix D-1. Of the various organic species in this water, DIMP was again found in the highest concentration with a maximum observed value of 1130 mg/l. Therefore a DIMP concentration of 500 mg/l was selected as the effluent breakthrough point at which the carbon treatment process was terminated for each GAC product under test. Throughout the testing period TOC ranged from <5 to 13 mg/l and pH from 6.8 to 8.1.

ANULAR ACTIVATED CARBON
PILOT COLUMNS
FLOW DIAGRAM

FIGURE 6



Appendices D-2, D-3 and D-4 summarize data on effluent quality for Carborundum GAC-40, Westvaco WV-L and Calgon Service Carbon products respectively. These data are also shown graphically in Figures 7, 8 and 9. For each GAC product the Figures reflect effluent data at contact times of 7.5, 15 and 30 minutes. From these data it can be seen that the volume of water treated per cubic foot of carbon is nearly identical for each contact time. Thus contact times above 7.5 minutes do not appear to reduce GAC dosage rates per gallon of water treated for the removal of DIMP. Overall organic reduction may be enhanced with contact times in excess of 7.5 minutes but the data is incomplete in this regard.

Figure 10 compares all three GAC products at 30 minute contact times. As can be seen the Carborundum GAC-40 and Westvaco WV-L performed nearly identical and treated about 39,000 gallons of water before DIMP breakthrough. This volume represents a carbon dosage of 0.84 pounds per 1000 gallons. The Calgon Service Carbon treated 26,000 gallons of water which results in a carbon dosage of 1.26 pounds per 1000 gallons.

Figure 11 shows the same comparison between Calgon Service Carbon and GAC-40 and WV-L on the basis of grams of DIMP removed. The Calgon product removed 75 grams of DIMP while the Carborundum and Westvaco GAC products removed 120 grams during the testing period. Complete data is listed in Appendix E.

Appendix D-4 shows the results of adsorption data in a single two-foot deep bed of Carborundum GAC-40 which was operated as the other columns but without pre-filtration. Throughout the period of column operation there was no evidence of solids build up in the column treating unfiltered water and headloss did not increase. The DIMP removal efficiency was comparable to that of the other pre-filtered columns containing the Carborundum and Westvaco carbons.

Algae growth in the sand filter necessitated backwashing of the filter once each week to prevent blinding at the surface. However, the same phenomenon was not observed in the unfiltered carbon column.

Shortly after starting the carbon adsorption column tests, air was observed within the carbon bed of the last column of each three-column series. Several unsuccessful attempts to prevent the air from accumulating were made by periodically opening the air bleed-off valve at the first column inlet. Dissolved oxygen (D.O.) readings taken intermittently indicated a D.O. level of 3.5-5.0 mg/l at the sand filter inlet, sand filter outlet and carbon column outlet. There was no pattern of D.O. increase or decrease at any point in the process.

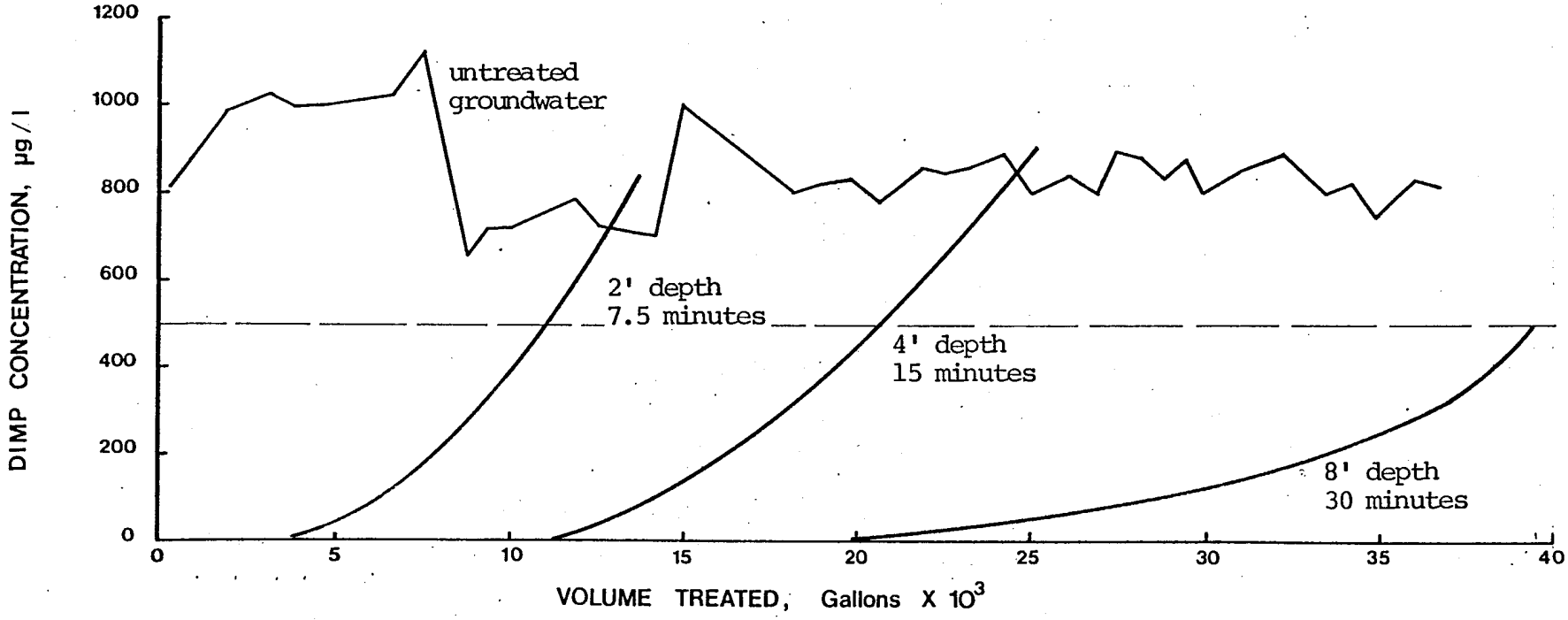


FIGURE 7

DIMP BREAKTHROUGH - CARBORUNDUM GAC-40 ACTIVATED CARBON

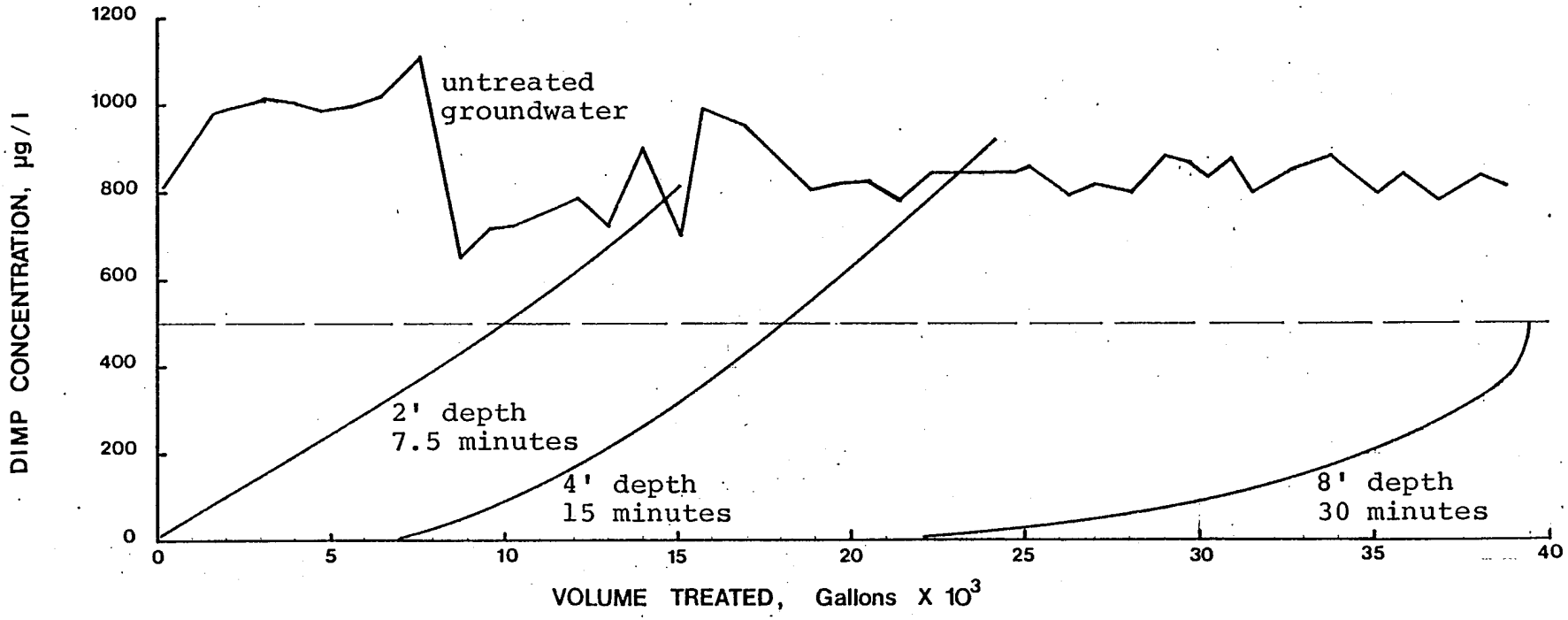


FIGURE 8

DIMP BREAKTHROUGH - WESTVACO WV-L ACTIVATED CARBON

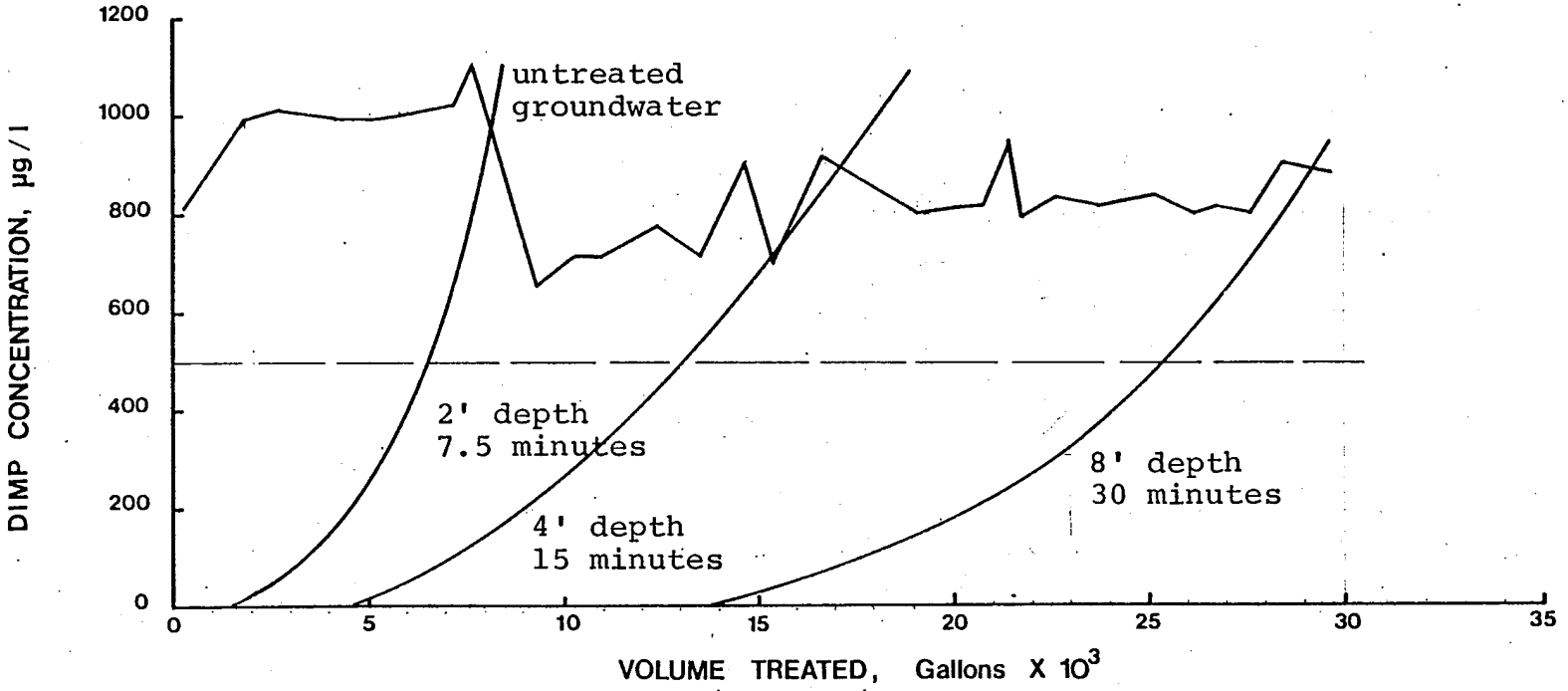


FIGURE 9

DIMP BREAKTHROUGH - CALGON SERVICE CARBON

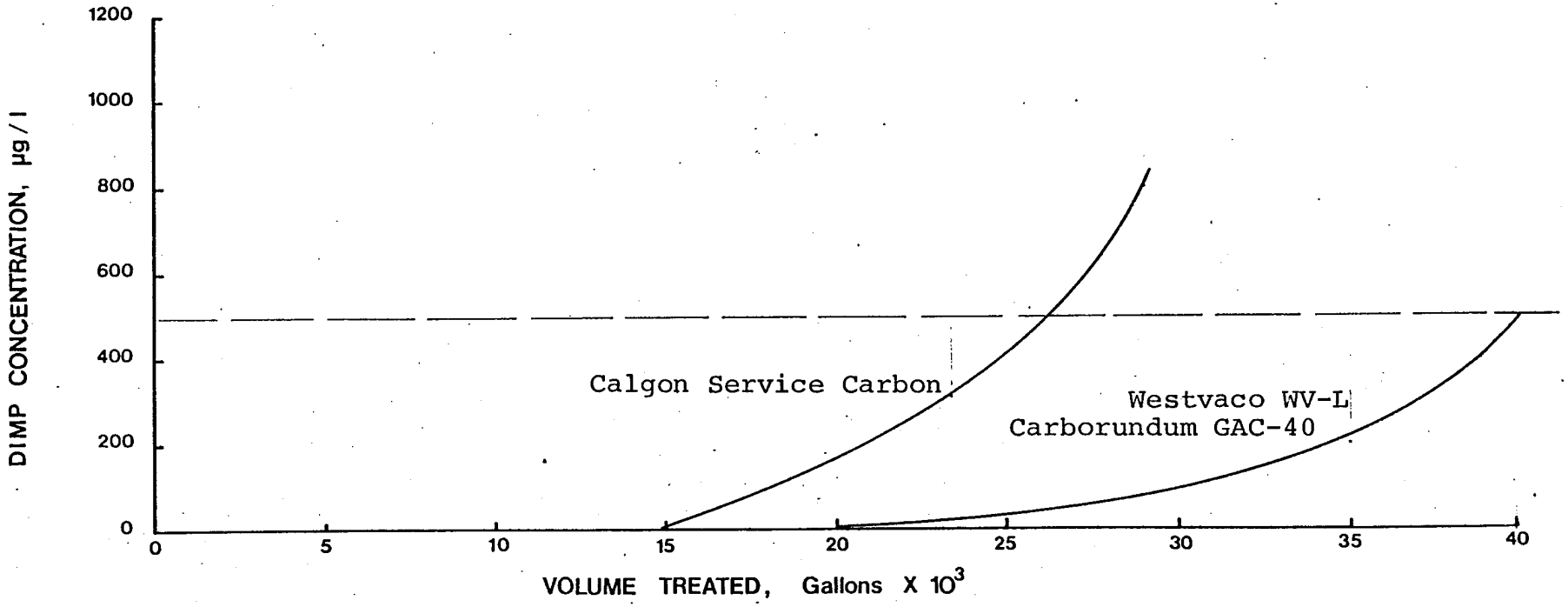
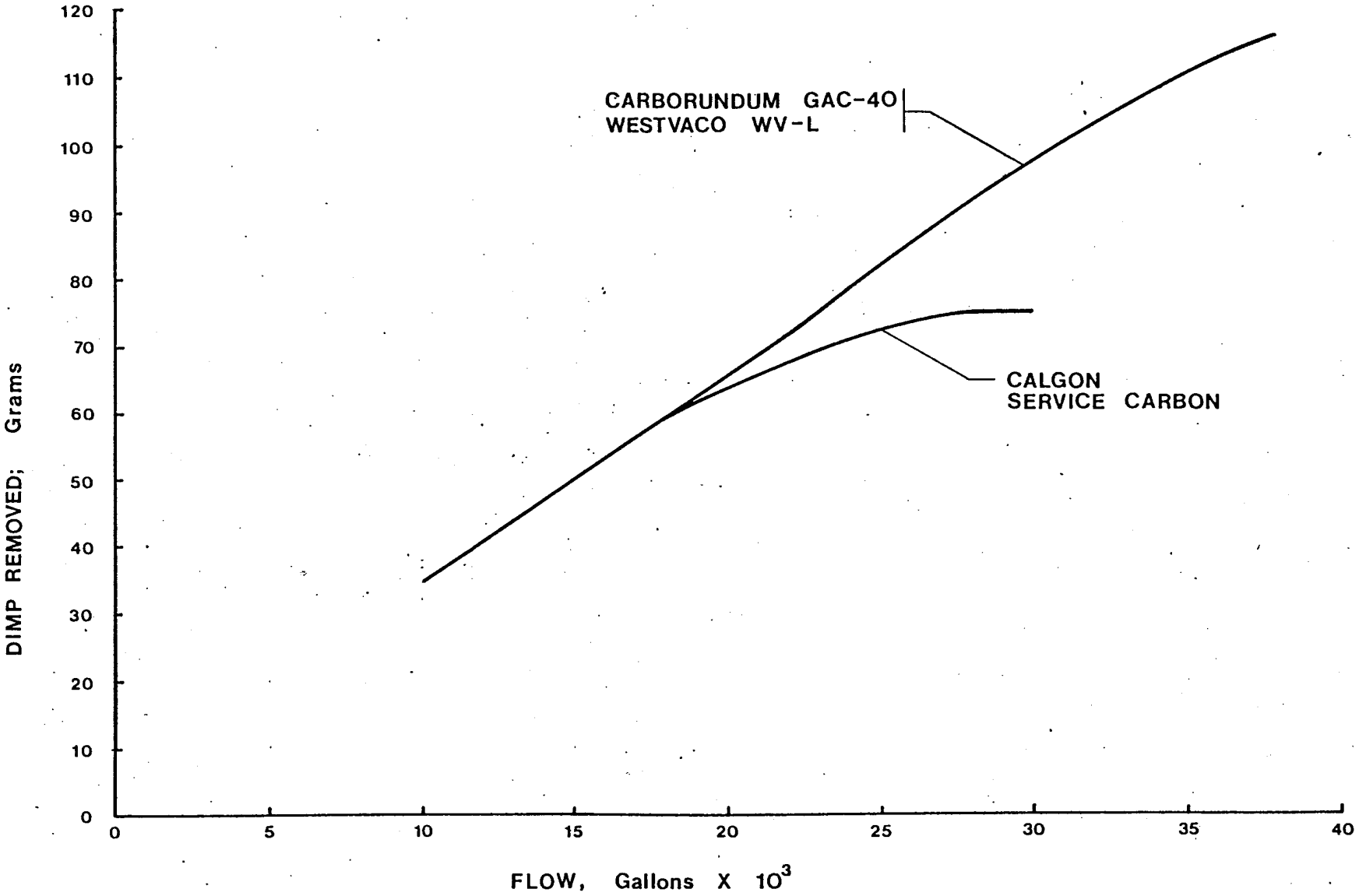


FIGURE 10

COMPARISON OF THREE ACTIVATED CARBONS

DIMP CONCENTRATION AFTER TREATMENT- 30 MINUTES CONTACT TIME



GRAMS OF DIMP REMOVED vs. VOLUME OF GROUNDWATER TREATED

FIGURE 11

CONCLUSIONS

1. There are three domestic manufacturers of coal based granular activated carbon which would be suitable for use at the RMA North Boundary Treatment Project: Westvaco, Calgon and Carborundum.

2. Dynamic column breakthrough tests indicated that Westvaco WV-L and Carborundum GAC-40 products were equal in performance and significantly better than Calgon Service Carbon.

3. Bench scale adsorption isotherm tests indicated that pH modification of the groundwater would not be cost effective.

4. Filtration testing indicated that filtration equipment is not likely to be needed in the full scale plant.

5. Carbon dosage rates for DIMP breakthrough at 500 μg/l on North Boundary groundwater is projected to be 0.84 pounds per 1000 gallons of water treated.

Nuchar®
granular activated carbons

Nuchar® WV-G

Description and Typical Applications

Nuchar WV-G is a hard, regenerable, granular activated carbon produced from selected grades of bituminous coal. The pore structure has been carefully controlled to provide a broad spectrum of pore sizes with a predominant number in the macro and transitional range. This wide range of pore sizes makes this carbon highly effective for the adsorption of both high and low molecular weight organics. It is particularly effective for the adsorption of large amounts of high molecular weight substances. The properties of *Nuchar WV-G 12x40* make it applicable in chemical and pharmaceutical purification and processing, for the removal of organics from potable water and for municipal and industrial wastewater treatment.

The density and particle size distribution make *Nuchar WV-G* well-suited for packed-bed adsorption applications. Its high resistance to abrasion results in minimum losses during thermal regeneration and mechanical handling. It can be used in either fixed or moving bed processes.

Nuchar WV-G 12x40 can normally be regenerated by thermal reactivation. In some cases it can be regenerated by chemical treatment or steaming in place.

Specifications*

Abrasion Number (Ro-Tap)	75 min
Iodine Number (mg/g)	1050 min
Surface Area (Nitrogen BET Method) (m^2/g)	1100 min
Molasses Decolorizing Index	8.0 min
Moisture, as packed (%)	2.0 max
Water Solubles (%)	1.0 max
Particle Size (U.S. Sieve Series)	12 x 40
Oversize (%)	8.0 max
Undersize (%)	5.0 max
Uniformity Coefficient	1.8 max

Typical Properties*†

Apparent Density (lb/cu ft)	27-29
Apparent Density (kg/m^3)	433-465
Bed Density, Backwashed and Settled (lb/cu ft)	24-26
Bed Density, Backwashed and Settled (kg/m^3)	385-417
Effective Size (mm)	0.55-0.75
Mean Particle Diameter (mm)	0.90-1.20
Particle Density, Wetted in Water (g/cm^3)	1.30-1.40
Voids in Packed Bed (%)	
Backwashed and Settled	45-55
Poured Dry Fill	40-45

*Specifications and typical property data using Westvaco procedures.
†Typical properties are for general information and are not to be construed as purchase specifications.

Packaging

Nuchar WV-G is shipped in bulk trucks, bulk rail cars, bulk boxes, or in multiwall paper bags in telescoping, corrugated boxes. The bulk boxes and bags-in-a-box are shipped on nonreturnable, wooden pallets with four-way double entry.

Pressure Drop Characteristics

The pressure drop per foot of backwashed and settled bed depth is presented in Figure 1 for various superficial velocities treating water at 25°C. For other conditions the pressure drop may be calculated from the equation:

$$h_f = \frac{K \upsilon V_s L}{g} \frac{1}{(d_{50})^2}$$

where:

h_f = head loss due to friction (ft of H_2O)
K = a constant equal to 550
υ = kinematic viscosity (sq ft/sec)
V_s = superficial velocity (ft/sec)
L = backwashed and settled bed depth (ft)
d_{50} = mean particle diameter (ft)
g = acceleration due to gravity (32.2 ft/sec²)

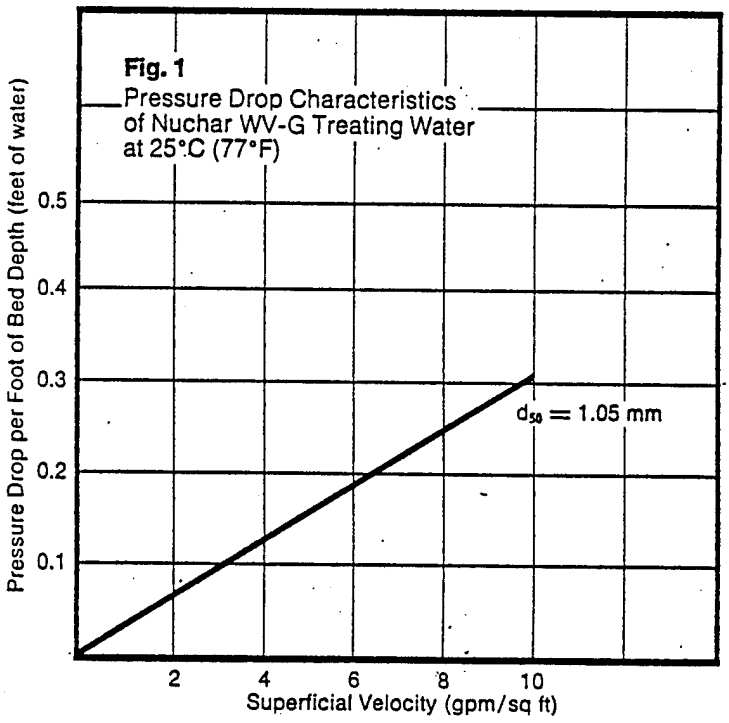


Fig. 1
Pressure Drop Characteristics of Nuchar WV-G Treating Water at 25°C (77°F)

Backwash Characteristics

The bed expansion achieved at various backwash rates is shown in Figure 2 for water at 25°C (77°F). The expansion is expressed as a percentage of the backwashed and settled bed depth.

CAUTION: Never enter tanks or other confined areas containing wet, activated carbon. Wet, activated carbon will adsorb oxygen and asphyxiation may result.

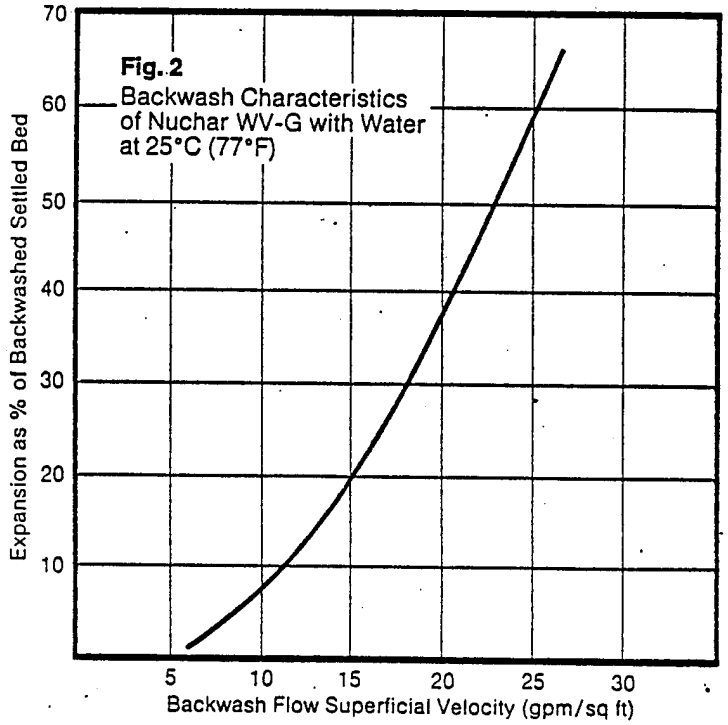


Fig. 2
Backwash Characteristics of Nuchar WV-G with Water at 25°C (77°F)

Westvaco
Chemical Division
Carbon Department
Covington, Virginia 24426
(703) 962-1121

The Carborundum Company
Activated Carbon Division
P.O. Box 1054
Niagara Falls, New York 14302
Telephone 716/278-6363
A Kennecott Company

Carborundum™ Granular Activated Carbon

Product Specifications

Carborundum GAC 40 Water and Waste Water Treatment Granular Carbon

Product Description

Carborundum Granular Activated Carbon is made from a select grade of coal which is sized, milled, compacted, and thermally activated to yield a strong, dense product with a large surface area. The pore structure is carefully controlled under rigid process conditions to facilitate adsorption of both high and low molecular weight organic impurities from water. Readily wettable, the activated product does not float and its high density permits efficient backwashing under conventional flow rate conditions.

Typical Applications

Carborundum GAC 40 is specially produced with a broad range of pores capable of adsorbing a variety of molecular weight organics from water and waste waters. GAC 40's particle size distribution is such that it can also perform as a filter to remove suspended solids which can be readily backwashed from the carbon granules. The carbon's resistance to attrition allows it to be hydraulically transported from the adsorption vessel to be thermally regenerated and returned with minimal losses.

GAC 40	Specification	Average Values*
U.S. Standard Series		
Sieve Size—12 x 40		
Greater than No. 12	5% max.	4%
Less than No. 40	5% max.	4%
Iodine Number—mg/g	1000 min.	1050
Abrasion Number (Ro-Tap)	75 min.	80
Mean Particle Diameter—mm	0.9—1.1	1.0%
Moisture Content	2.0% max.	1.0%

Typical Properties*	Value*
Total Surface Area (N_2 BET Method)—m^2/g	1000—1100
Apparent Density—lb/ft^3	29
g/cm^3	0.47
Backwashed and Drained Density—lb/ft^3	25
g/cm^3	.40
Effective Size—mm	0.60
Particle Density Wetted in H_2O—g/cm^3	1.35
Uniformity coefficient	1.90 or less

*For general information and not to be used as purchase specifications.

Form A-11,021
Effective 5/79

CARBORUNDUM

PITTSBURGH ACTIVATED CARBON

TYPE CAL® GRANULAR CARBON
AND FS 400

Type CAL is a granular decolorizing carbon designed for efficient use in fixed beds or moving beds for the purification and decolorization of many aqueous and organic liquids. Its particle size of 12 x 40 mesh has been selected to give a high rate of adsorption and low resistance to flow with liquors of medium viscosity.

Type CAL Carbon is made from selected grades of bituminous coal combined with suitable binders to give superior hardness and long life. Produced under rigidly controlled conditions by high temperature steam activation, this carbon provides high surface area, large pore volume, high density and a pore structure optimum for the adsorption of color bodies and odor molecules from solutions.

Typical Applications: One of the largest applications for Pittsburgh Type CAL is in beet sugar refining where liquors of exceptionally low floc characteristics must be produced. The high adsorption capacity of CAL in fixed or moving beds permits continuous decolorizing cycles, after which the carbon can be thermally reactivated for repeated use. The advantages and economy of Type CAL systems have also found wide acceptance in the chemical process industries for the decolorization and purification of numerous aqueous and organic liquids. Typical of these are citric acid, glycerine, urea, monosodium glutamate, organic esters, soda ash, caustic liquors and muriatic acid.

Economy of Column Operation: The use of highly active Pittsburgh Granular Carbons in fixed or moving beds provides the ultimate in countercurrent efficiency and simplicity of operation. The columns, which are sometimes as small as 1 foot in diameter and 8 feet in height, eliminate the need for slurry tanks, filter presses, and multiple treatment with powdered carbon. A properly designed system offers:

1. A cleaner, continuous operation.
2. More efficient utilization of the activated carbon — more impurities adsorbed per pound of carbon.
3. Less equipment — less floor space.
4. Lower carbon dosage — lower costs.
5. Improved product quality — better colors, plus odor removal.

PHYSICAL PROPERTIES

Total Surface Area (N_2, BET Method†), m^2/g	1000-1100
Apparent Density (Bulk Density, dense packing), g/cc	0.44
lb/ft³	27.5
Density as packed in column lb/ft³	25
Particle Density (Hg Displacement), g/cc	0.7
Real Density (He Displacement), g/cc	2.1
Pore Volume (Within Particle), cc/g	0.94
Voids in Dense Packed Column, %	38
Specific Heat at 100° C	0.25
pH	7.5

†Brunauer, Emmett and Teller: J. Am. Chem. Soc. *60*, 309 (1938)

SPECIFICATIONS

Mesh Size, U.S. Sieve Series	12 x 40
Larger than 12 mesh, Maximum, %	5
Smaller than 40 mesh, Maximum, %	4
Mean Particle Diameter, mm	.9-1.1
Iodine Number, Minimum	1000
Molasses Number, Minimum	230
Ash, Maximum, %	10
Moisture as packed, Maximum, %	2.0
Abrasion Number, Minimum	75

COMMERCIAL INFORMATION

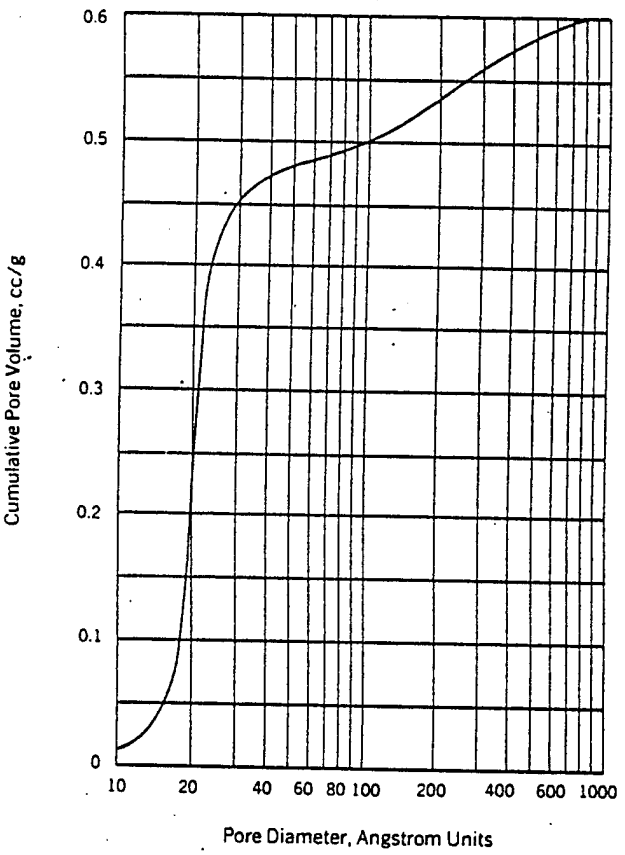
Shipping Points: Pittsburgh, Pennsylvania; Catlettsburg, Kentucky.

Packaging: Type CAL Carbon is packed in four-ply kraft bags, 60 pounds net weight, 61 pounds gross weight.

PORE STRUCTURE

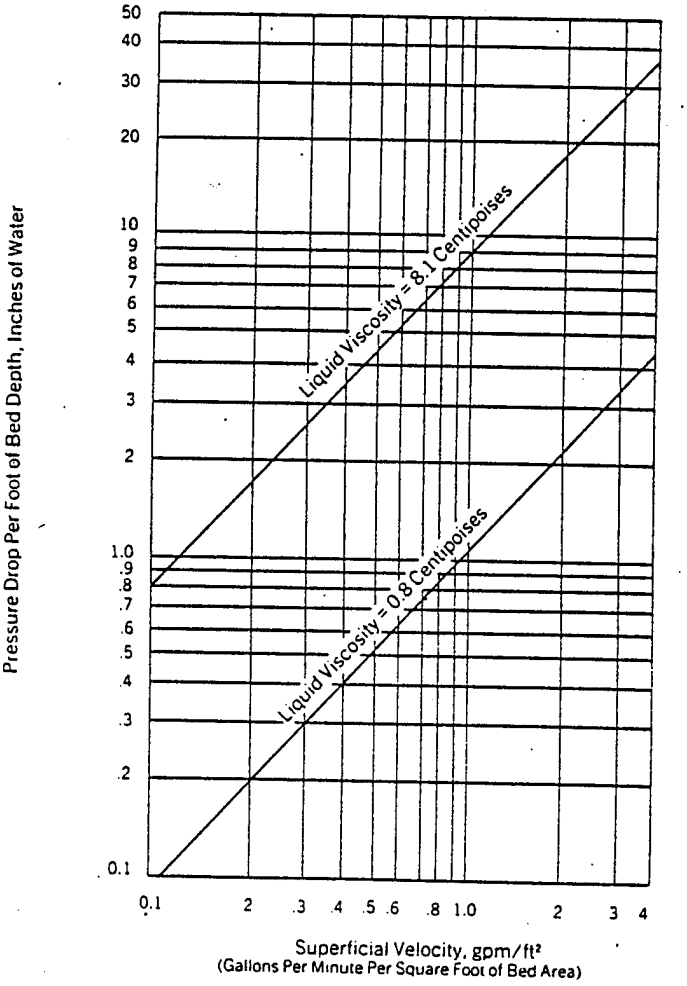
The pore structure of Type CAL Carbon is illustrated at the right, where cumulative pore volume is plotted against pore diameter. Correlation studies have shown that adsorption capacity is determined in part by total pore volume and pore size distribution. Decolorizing power is derived primarily from those pores within the 20 to 100 Angstrom Unit range. Type CAL Carbon, as shown at the right, has a high percentage of its total pore volume in this important range, as well as sufficient smaller pores for the adsorption of odor molecules.

In addition, each granule of Type CAL is completely permeated by a system of large macropores which serve as avenues for the rapid diffusion of color bodies to the small pore surfaces. This enhances both adsorption and reactivation characteristics.



PRESSURE DROP CHARACTERISTICS

Pressure drop per foot of bed depth for Type CAL Carbon can be read at the right for varying flow rates at two different viscosity levels. The 0.8 centipoise line corresponds to water at 72° F, while the 8.1 centipoise line is equivalent to a 63.5 Brix sugar solution at 170° F. These data were obtained in downflow column operation with a normal packing arrangement in which the carbon was pre-soaked in hot liquid and charged to the column as a slurry. The bulk density of the charged carbon was calculated to be approximately 25 lb/ft³.



REACTIVATION

In those applications where the volume of carbon in service is large, further savings can be realized through the reactivation of Pittsburgh CAL for continued use in repeated cycles. Partial reactivation can sometimes be accomplished by chemical treatment without removing the carbon from the columns. In other cases, it is more satisfactory to use high temperature processing equipment such as the Herreshoff multiple-hearth furnace or direct-fired rotary kilns. Equipment of this type is maintained at our Pittsburgh plant in order to provide reactivation service at a nominal cost.

For samples and technical information write or call:

PITTSBURGH ACTIVATED CARBON
DIVISION OF CALGON CORPORATION
SUBSIDIARY OF MERCK & CO., INC.

CALGON CENTER, BOX 1346, PITTSBURGH, PA. 15230
(412) 923-2345

APPENDIX B

ADSORPTION ISOTHERM PROCEDURE

1. Pulverize a representative sample of the granular carbon (a 25-30 gram sample is usually adequate) so that 95 wt.% will pass through a 325 mesh screen. Oven-dry the pulverized sample for three hours at 150°F.

2. Obtain a representative sample of the liquid to be tested. Any suspended matter should be removed by filtration.

3. From the oven-dried pulverized sample, weigh out the carbon samples on an analytical balance and transfer the weighed samples to suitable shaker flasks.

4. Measure 800 ml of well water into each flask. After manually swirling to make certain all the carbon is wetted, clamp each flask on the shaker. Also place 800 ml of well water in a flask without carbon (this will serve as the "blank" or control sample) and place it on the shaker with the other flasks. Agitate all the flasks at the desired temperature for three hours.

5. After the required contact time has elapsed, separate the carbon from the liquid by filtering through a 0.45 um filter.

6. Determine the residual adsorbate in solution for each of the samples by the appropriate method for detecting that particular material.

7. Record the data and plot the results on the Adsorption Isotherm Test Data Sheet. (R/H form 9/80)

APPENDIX C-1
ROCKY MOUNTAIN ARSENAL
NORTH BOUNDARY GROUND WATER

CALGON CARBON ADSORPTION ISOTHERM TEST DATA

SAMPLE NO.	WT. CARBON (mg)	TEST pH	ORGANIC CONCENTRATION (µg/l) DIMP	DITH	OXAT	DBCP	CPMSO	CPMO2	PCPMS
Pl 2200	0	7.8	769	<20	<20	0.37	<20	42.8	<20
Pl 2201	26.64		516	<20	<20	0.20	<20	<20	<20
Pl 2202	49.90		333	<20	<20	<0.20	<20	<20	<20
Pl 2203	99.90		107	<20	<20	<0.20	<20	<20	<20
Pl 2204	250.00		14.2	<20	<20	<0.20	<20	<20	<20
Pl 2205	500.22		<10	<20	<20	<0.20	<20	<20	<20
Pl 2206	0	9.0	644	<20	<20	0.43	<20	39.5	<20
Pl 2207	25.05		205	<20	<20	<0.20	<20	<20	<20
Pl 2208	50.00		246	<20	<20	<0.20	<20	<20	<20
Pl 2209	100.05		86.7	<20	<20	<0.20	<20	<20	<20
Pl 2210	250.00		11.8	<20	<20	<0.20	<20	<20	<20
Pl 2211	499.91		<10	<20	<20	<0.20	<20	<20	<20
Pl 2212	0	6.0	652	<20	<20	0.67	<20	36.5	<20
Pl 2213	25.04		345	<20	<20	<0.20	<20	<20	<20
Pl 2214	50.		420	<20	<20	<0.20	<20	<20	<20
Pl 2215	100.20		170	<20	<20	<0.20	<20	<20	<20
Pl 2216	249.96		<10	<20	<20	<0.20	<20	<20	<20
Pl 2217	500.11		<10	<20	<20	<0.20	<20	<20	<20
Pl 2218	0	4.0	717	<20	<20	0.51	<20	32.2	<20
Pl 2219	24.85		608	<20	<20	<0.20	<20	<20	<20
Pl 2220	50.06		494	<20	<20	<0.20	<20	<20	<20
Pl 2221	100.23		274	<20	<20	<0.20	<20	<20	<20
Pl 2222	249.95		22.9	<20	<20	<0.20	<20	<20	<20
Pl 2223	499.84		<10	<20	<20	<0.20	<20	<20	<20

APPENDIX C-2
ROCKY MOUNTAIN ARSENAL

WESTVACO CARBON ADSORPTION ISOTHERM TEST DATA

SAMPLE NO.	WT. CARBON (mg)	TEST pH	ORGANIC CONCENTRATION (µg/l) DIMP	DITH	OXAT	DBCP	CPMSO	CPM02	PCPMS
Pl 2230	0	7.8	716	<20	<20	0.28	<20	41.7	<20
Pl 2231	25.11		589	<20	<20	<0.20	<20	<20	<20
Pl 2232	50.06		253	<20	<20	<0.20	<20	<20	<20
Pl 2233	100.06		68.4	<20	<20	<0.20	<20	<20	<20
Pl 2234	249.90		12.3	<20	<20	<0.20	<20	<20	<20
Pl 2235	500.06		<10	<20	<20	<0.20	<20	<20	<20
Pl 2236	0	9.0	777	<20	<20	0.37	<20	27.6	<20
Pl 2237	25.08		561	<20	<20	<0.20	<20	<20	<20
Pl 2238	50.20		264	<20	<20	<0.20	<20	<20	<20
Pl 2239	99.89		52.6	<20	<20	<0.20	<20	<20	<20
Pl 2240	249.93		<10	<20	<20	<0.20	<20	<20	<20
Pl 2241	500.10		<10	<20	<20	<0.20	<20	<20	<20
Pl 2242	0	6.0	875	<20	<20	0.34	<20	39.0	<20
Pl 2243	25.02		494	<20	<20	<0.20	<20	<20	<20
Pl 2244	49.94		397	<20	<20	<0.20	<20	<20	<20
Pl 2245	100.07		87.6	<20	<20	<0.20	<20	<20	<20
Pl 2246	250.18		12.1	<20	<20	<0.20	<20	<20	<20
Pl 2247	499.71		<10	<20	<20	<0.20	<20	<20	<20
Pl 2248	0	4.0	828	<20	<20	0.30	22.1	41.2	<20
Pl 2249	24.21		694	<20	<20	<0.20	<20	<20	<20
Pl 2250	50.23		504	<20	<20	<0.20	<20	<20	<20
Pl 2251	99.91		140	<20	<20	<0.20	<20	<20	<20
Pl 2252	250.32		15	<20	<20	<0.20	<20	<20	<20
Pl 2253	499.96		<10	<20	<20	<0.20	<20	<20	<20

APPENDIX C-3
ROCKY MOUNTAIN ARSENAL

CARBORUNDUM CARBON ADSORPTION ISOTHERM TEST DATA

SAMPLE NO.	WT. CARBON (mg)	TEST pH	DIMP	DITH	ORGANIC CONCENTRATION (µg/l) OXAT	DBCP	CPMSO	CPMO2	PCPMS
Pl 2260	0	7.8	642	18.9	2.43	0.12	0	43.7	0
Pl 2261	25.13		449	13.4	2.87	<0.20	0	0	0
Pl 2262	50.01		242	8.23	2.78	<0.20	0	0	0
Pl 2263	100.09		53.8	3.07	0	<0.20	0	0	0
Pl 2264	250.04		5.2	2.10	0	<0.20	0	0	0
Pl 2265	499.94		1.7	0	0	<0.20	0	0	0
Pl 2266	0	9.0	655	17.2	0	<0.20	13.3	39.1	0
Pl 2267	25.08		456	12.1	0	<0.20	0	0	0
Pl 2268	50.10		213	8.3	0	<0.20	0	0	0
Pl 2269	100.07		39.5	3.43	4.2	<0.20	0	0	0
Pl 2270	250.07		4.1	0	0	<0.20	0	0	0
Pl 2271	500.02		2.6	0	0	<0.20	0	0	0
Pl 2272	0	6.0	725	23.1	4.3	<0.20	27.8	55	8.22
Pl 2273	25.06		532	15.1	3.8	<0.20	4.49	4.16	3.77
Pl 2274	49.98		297	9.5	3.74	<0.20	9.69	4.02	9.05
Pl 2275	99.91		74.7	4.52	3.03	<0.20	5.96	3.92	2.12
Pl 2276	249.98		6.4	2.14	1.91	<0.20	4.04	0	0
Pl 2277	499.99		1.9	0	0.96	<0.20	3.11	0	0
Pl 2278	0	4.0	679	19.5	3.83	<0.20	22.3	49.0	7.13
Pl 2279	24.99		585	15.7	3.59	<0.20	6.22	5.65	4.03
Pl 2280	50.05		390	9.42	3.35	<0.20	16.2	3.30	26.6
Pl 2281	100.00		118	7.15	4.63	<0.20	12.3	6.9	0
Pl 2282	249.88		8.3	1.77	1.15	<0.20	4.0	0	0
Pl 2283	500.07		2.1	0	0	<0.20	4.05	0	0

APPENDIX D-1

ACTIVATED CARBON PILOT PLANT TEST DATA

FILTERED NORTH BOUNDARY GROUND WATER

DATE	SAND FILTER PRESSURE in psi out	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	pH
1/15/81 Started Pilot Plant										
1/16	8	813	0.31	<20	<20	<20	<20	<20	10.8	7.5
1/18	8		0.25						9	
1/20	11	995							9	
1/23	11	1020							8.3	
1/26	9	999	0.33	<20	<20	<20	<20	<20		
1/28	9	984								
1/30	9	994								
2/2	10	1030	0.43	<20	<20	<20	<20	36	9	
2/4	11	1130								
2/9	10	647	0.39	<20	21.1	<20	21.2	54.1		
2/11	9	721							13	7.4
2/13	9	720							11	
2/17	9.5	788	0.37	<20	21.9	<20			7.6	
2/20	9	731							9	7.
2/23	8.5	904	<0.2	<20	21.1	<20	<20	<20	<5	7.8
2/25	7.5	704							13	
2/27	8	998							11	
3/2	8.5	937		<20	24.4	<20	<20	42.2	11	7.2
3/9	8	801	1.03	<20	<20	<20	<20	<20	10	6.8
3/11	9	816								

APPENDIX D- 1 (Continued)

ACTIVATED CARBON PILOT PLANT TEST DATA

FILTERED NORTH BOUNDARY GROUND WATER

DATE	SAND FILTER PRESSURE in psi out	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	pH
3/13	7	820							10.5	
3/17	6	788	0.28	<20	<20	<20	<20	44.3	9.3	7.7
3/20	8	859							8.1	
3/23	8	849	0.27	<20	48.6	25.6	<20	61.5	7.9	
3/25	7.5	862							7	
3/27	8	875							7.6	
3/30	8	798	0.54	<20	64	34.6	<20	33.7	7.6	7.3
4/1	7.5	827							8	
4/3	9	801							<5	
4/6	9.5	896	0.23	<20	21.2	<20	<20	29.7	<5	8.1
4/8	7.5	878							6.8	
4/13	7	833	0.59	22.9		<20	<20	36.2	11.2	7.6
4/15	8	881							9.3	
4/17	8	802							5.9	
4/20	7	859	0.48						5.9	
4/22	9									
4/24	9	893							10	
4/27	9.5	801	0.45							7.5
4/29	10	839							7	
5/1	9.5	769							9	
5/4	8	854								7.5
5/6	7.5	842								

APPENDIX D- 2

ACTIVATED CARBON PILOT PLANT TEST DATA

CARBORUNDUM GAC-40 EFFLUENT

DATE	PRESS.	COL	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
1/15 Start											
1/16	0	1	<10	<0.2	<20	<20	<20	<20	<20		316
		2	<10	<0.2	<20	<20	<20	<20	<20		
		3	<10	<0.2	<20	<20	<20	<20	<20	<5	
1/20	8	1	<10							<5	1787
1/23	10	1	<10							<5	2743
1/26	6	1	<10	<0.2	<20	<20	<20	<20	<20		3798
1/28	2	1	27.2								4606
1/30		1	29.6								5353
		2	10		<20	<20	<20	<20	<20		
2/2		1	35	<0.2	<20	<20	<20	<20	<20		6532
		2	10	<0.2	<20	<20	<20	<20	<20		
2/4	2	1	44.4								7152
		2	10								
2/9	8	1	200	<0.2	<20	<20	<20	<20	<20		8518
		2	10	<0.2	<20	<20	<20	<20	<20		
2/11	4	1	416							10	9346
		2	10							7	
2/13	2	1	420							15	10065
		2	10							8	
2/17	4	1	707	<0.2	33.5	<20	<20	<20	<20	5.5	11662
		2	10	<0.2	<20	<20	<20	<20	<20	4.8	
		3	10	<0.2	<20	<20	<20	<20	<20	1.9	

APPENDIX D-2 (Continued)
ACTIVATED CARBON PILOT PLANT TEST DATA
CARBORUNDUM GAC-40 EFFLUENT

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
2/20		1	674							<5	12566
		2	22.7							4	
2/25	4	1	757							13	13958
		2	68.2							8	
		3	<10							3	
2/27		2	56.3							8	14756
		3	<10							5	
3/2		2	140	<0.2	<20	<20	<20	<20	<20	8.3	15863
		3	<10	<0.2	<20	<20	<20	<20	<20	4.4	
3/9	6	2	304	<0.2	<20	<20	<20	27	<20	8	18133
		3	<10	<0.2	<20	<20	<20	<20	<20	<5	
3/11	8	2	456							8.3	18835
		3	<10							7.7	
3/13		2	515							8.8	19621
		3	<10							6.4	
3/17	4	2	616	<0.2						7.2	20501
		3	12.2	<0.2	<20	<20	<20	<20	<20	5.6	
3/20	6	2	663							6.6	21669
		3	<10							4.3	
3/23		2	579	<0.2	<20	<20	<20	<20	46	6.8	22358
		3	<10	<0.2	<20	<20	<20	<20		5.9	
3/25		2	693							6.0	23162

APPENDIX D-2 (Continued)
ACTIVATED CARBON PILOT PLANT TEST DATA
CARBORUNDUM GAC-40 EFFLUENT

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
3/27		2	891							5.7	23888
		3	18							<5	
3/30		2	703	<0.2	<20	<20	<20	<20	<20	5.7	24987
		3	17	<0.2	<20	<20	<20	<20	<20	<5	
4/1		3	25.8							6	25764
4/3		3	45.1							5	26453
4/6		3	33.7	<0.2	<20	<20	<20	<20	<20	<5	27374
4/8		3	51.4							<5	28029
4/13		3	38	<0.2	<20	<20	<20	<20	<20	8.9	28783
4/15		3	86							7.5	29322
4/17		3	47.7							4.0	29953
4/20		3	49.8	<0.2						2.1	30892
4/22		3								7	31637
4/24		3	153								32365
4/27		3	199	<0.2							334
4/29		3	178							<5	34155
5/1		3	182							5	34918
5/4		3	232								36150
5/6		3	308								36862

APPENDIX D-3
ACTIVATED CARBON PILOT PLANT TEST DATA
WESTVACO WV-L EFFLUENT

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
1/15 Start											
1/16	0	1	<10	<0.2	<20	<20	<20	<20	<20		305
		2	<10	<0.2	<20	<20	<20	<20	<20		
		3	<10	<0.2	<20	<20	<20	<20	<20	<5	
1/20		1	233							<5	1717
1/23		1	82.4							<5	3155
1/26	4	1	24.3		<20	<20	<20	<20	<20		4040
1/28		1	225								4831
		2	<10								
1/30		1	318								5672
		2	<10								
2/2		1	388	<0.2	<20	<20	<20	<20	<20		6764
		2	<10	<0.2	<20	<20	<20	<20	<20		
2/4		1	615								7555
		2	11.2								
2/9	6	1	463	<0.2	<20	<20	<20	<20	<20		8861
		2	12.7	<0.2	<20	<20	<20	<20	<20		
2/11		1	594							11	9692
		2	61							9	
2/13		1	639							10	10442
		2	127							8	

APPENDIX D-3 (Continued)

ACTIVATED CARBON PILOT PLANT TEST DATA

WESTVACO WV-L EFFLUENT

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
2/17	2	1	758	<0.2	<20	<20	<20	<20	<20	8	12071
		2	234	<0.2	32.4	<20	<20	<20	<20	4	
		3	<10	<0.2	<20	<20	<20	<20	<20	<2	
2/20		2	279							5	12(
		3	<10							6	
2/23		1	786	<0.2	<20	<20	<20	<20	<20	<5	14309
		2	412	<0.2	<20	<20	<20	<20	<20	<5	
2/25	2	1	723							11	15124
		2	411							11	
		3	<10							7	
2/27		2	38.9							10	15875
		3	<10							8	
3/2		2	796	<0.2	<20	<20	<20	<20	<20	9.6	17111
		3	<10	<0.2	<20	<20	<20	<20	<20	5	
3/9	5	2	416	<0.2	<20	<20	<20	<20	<20	8	19(
		3	<10	<0.2	<20	<20	<20	<20	<20	<5	
3/11		2	699							10.3	19856
		3	<10							7.7	
3/13		2	642							9.6	20611
		3	<10							6.7	
3/17		2	644	<0.2	<20	<20	<20	<20	<20	7.6	21457
		3	<10	<0.2	<20	<20	<20	<20	<20	6	

APPENDIX D- 3 (Continued)
ACTIVATED CARBON PILOT PLANT TEST DATA
WESTVACO WV-L EFFLUENT

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
3/20		2	929							6.6	22551
		3	<10							4.3	
3/23		2	744	<0.2	<20	<20	<20	<20	<20	7	23882
		3	11	<0.2	<20	<20	<20	<20	<20	<5	
3/25		2	673							6.2	24662
		3	10.8							<5	
3/27		3	37.6							<5	25348
3/30		3	47.3	<0.2	<20	<20	<20	<20	<20	5.3	26517
4/1		3	68.4							6	27312
4/3		3	93.4							<5	28092
4/6		3	88.4	<0.2	<20	<20	<20	<20	<20	<5	29183
4/8		3	137							<5	29876
4/13		3	87.5							8.4	30572
4/15		3	87.5							7.9	31060
4/17		3	76.5							4	31(
4/20		3	78.8							3.6	32592
4/22		3								7	33338
4/24		3	251								34066
4/27		3	141	<0.2							35060
4/29		3	223							<5	35647
5/1		3	301							6	36361
5/4		3	350								37514
5/6		3	400								38265

APPENDIX D-4

ACTIVATED CARBON PILOT PLANT TEST DATA

CALGON SERVICE CARBON

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
1/15 Start											
1/16	0	1	<10	<0.2	<20	<20	<20	<20	<20		309
		2	<10	<0.2	<20	<20	<20	<20	<20		
		3	<10	<0.2	<20	<20	<20	<20	<20		
1/20		1	<10							7.3	1877
1/23		1	41.6							<5	2863
1/26		1	301								4147
1/28		1	581								5046
		2	17.9								
1/30		1	580								5880
		2	<10								
2/2		1	661	<0.2	<20	<20	<20	<20	<20		7079
		2	23	<0.2	<20	<20	<20	<20	<20		
2/4		1	898								7876
		2	65.1								
2/9		2	316	<0.2	<20	<20	<20	<20	<20		9498
2/11		2	353							10	10317
		3	<10							11	
2/13		1	763							11	11040
		2	454							9	
2/17		1	798	<0.2	23.1	<20	<20	<20	<20	6.6	12617
		2	52.7	<0.2	<20	<20	<20	<20	<20	4.5	
		3	<10	<0.2	<20	<20	<20	<20	<20	2.9	

APPENDIX D- 4 (Continued)
ACTIVATED CARBON PILOT PLANT TEST DATA
CALGON SERVICE CARBON

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
2/20	0	2	541							8	13352
		3	<10							4	
2/23		2	890	<0.2	<20	<20	<20	<20	<20	<5	14683
		3	16.3	<0.2	<20	<20	<20	<20	<20	<5	
2/25		1	729							11	15417
		2	659							9	
		3	44.5							8	
2/27		3	21.4							11	16134
3/2		2	1100	<0.2	<20	<20	<20	<20	<20	8.3	16955
		3	32	<0.2	<20	<20	<20	<20	<20	8.3	
3/9		2	876	<0.2						8	19340
		3	84.9	<0.2						<5	
3/11		3	263							9.8	20219
3/13		3	259							8.0	20967
3/17		3	254	<0.2	<20	<20	<20	<20	<20	7.6	21[illegible]
3/20		3	364							5.8	22916
3/23		3	297	<0.2	<20	<20	<20	<20	<20	7	23710
3/25		3	392							7.9	24510
3/27		3	457							5	25259
3/30		3	433	<0.2	<20	<20	<20	<20	<20	5.7	26155

APPENDIX D- 4 (Continued)
ACTIVATED CARBON PILOT PLANT TEST DATA
CALGON SERVICE CARBON

DATE	PRESS.	COL.	DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
4/1		3	620							6	26950
4/3		3	821							< 5	27742
4/6		3	811	< 0.2	< 20	< 20	< 20	< 20	< 20	< 5	28787
4/8		3	839							< 5	29

APPENDIX D- 5

ACTIVATED CARBON PILOT PLANT TEST DATA

CARBORUNDUM GAC-40 (NO PRE FILTER)

DATE		DIMP µg/l	DBCP µg/l	OXAT µg/l	DITH µg/l	PCPMS µg/l	CPMSO µg/l	CPMO2 µg/l	TOC mg/l	FLOW gal.
1/15	Start									
1/16		<10	<0.2	<20	<20	<20	<20	<20		352
1/20		<10							<5	2086
1/23		<10							<5	337
1/26		<10	<0.2	<20	<20	<20	<20	<20		4842
1/28		<10								5801
1/30		31.6								6834
2/2		134	<0.2	<20	<20	<20	<20	<20		8306
2/4		468								9187
2/9		581	<0.2	<20	<20	<20	<20	<20		11062
2/11		676							11	12046
2/17		850	<0.2	<20	<20	<20	<20	<20	4.5	14933
2/20		772							7	15848
2/23		880	<0.2	<20	<20	<20	<20		<5	17215
2/25		889							11	1795[illegible]

APPENDIX E-1

DIMP REMOVAL BY CARBORUNDUM GAC-40

DATE	FLOW l	INITIAL CONCEN. AVG. µg/l	g IN	FINAL CONCEN. µg/l	g OUT	GRAMS REMOVED INCREMENTAL	GRAMS REMOVED CUMULATIVE
1/16	1,199	813	0.975	<10	0	0.975	0.975
2/17	42,945	903	38.78	<10	0	38.78	39.755
2/25	8,690	782	6.796	<10	0	6.796	46.551
2/27	3,020	851	2,570	<10	0	2.570	49.121
3/2	4,190	968	4.056	<10	0	4.056	53.177
3/9	8,592	869	7.466	<10	0	7.466	60.643
3/11	2,657	808	2.147	<10	0	2.147	62.79
3/13	2,975	818	2.434	<10	0	2.434	65.224
3/17	3,331	804	2.678	12.2	0.041	2.637	67.861
3/20	4,421	823	3.638	<10	0	3.638	71.499
3/23	2,608	854	2.227	<10	0	2.227	73.726
3/27	5,791	862	4.992	18	0.104	4.888	78.614
3/30	4,160	837	3.482	17	0.071	3.411	82.025
4/1	2,941	813	2.391	25.8	0.076	2.315	84.34
4/3	2,608	814	2.123	45.1	0.118	2.005	86.345
4/6	3,486	849	2.960	33.7	0.117	2.843	89.188
4/8	2,479	887	2.199	51.4	0.127	2.072	91.26
4/13	2,854	856	2.443	38	0.108	2.335	93.595
4/15	2,078	857	1.781	86	0.179	1.602	95.197
4/17	2,388	842	2.011	47.7	0.114	1.897	97.094
4/20	3,554	831	2.953	49.8	0.177	2.776	99.87
4/24	5,575	876	4.884	153	0.853	4.031	103.901
4/27	4,054	847	3.434	199	0.807	2.627	106.528
4/29	2,721	820	2.231	178	0.484	1.747	108.275
5/1	2,888	804	2.322	182	0.526	1.796	110.071
5/4	4,663	812	3.786	232	1.082	2.704	112.775
5/6	2,695	848	2.285	308	0.830	1.455	114.23

APPENDIX E-2
DIMP REMOVAL BY WESTVACO WV-L

DATE	FLOW l	INITIAL CONCEN. AVG. µg/l	g IN	FINAL CONCEN. µg/l	g OUT	GRAMS REMOVED INCREMENTAL	GRAMS REMOVED CUMULATIVE
1/16	1,154	813	0.938	<10	0	0.938	0.938
2/17	44,534	903	40.214	<10	0	40.214	41.152
2/20	3,198	760	2.430	<10	0	2.430	43.582
2/25	8,357	780	6.518	<10	0	6.518	50.10
2/27	2,843	851	2.419	<10	0	2.419	52.519
3/2	4,678	968	4.528	<10	0	4.528	57.047
3/9	7,271	869	6.318	<10	0	6.318	63.365
3/11	3,126	809	2.529	<10	0	2.529	65.894
3/13	2,858	818	2.338	<10	0	2.338	68.232
3/17	3,202	804	2.574	<10	0	2.574	70.806
3/20	4,141	824	3.412	<10	0	3.412	74.218
3/23	5,038	854	4.302	11	0.055	4.247	78.465
3/25	2,952	856	2.527	10.8	0.032	2.495	80.960
3/27	2,597	869	2.241	37.6	0.097	2.144	83.104
3/30	4,425	837	3.704	47.3	0.209	3.495	86.599
4/1	3,009	813	2.446	68.4	0.206	2.240	88.839
4/3	2,952	814	2.403	93.4	0.276	2.127	90.966
4/6	4,129	849	3.506	88.4	0.365	3.141	94.107
4/8	2,623	887	2.327	137	0.359	1.968	96.075
4/13	2,634	856	2.255	87.5	0.230	2.025	98.100
4/15	1,847	857	1.583	87.5	0.162	1.421	99.521
4/17	2,339	842	1.969	76.5	0.179	1.790	101.311
4/20	3,459	831	2.874	78.8	0.273	2.601	103.912
4/24	5,579	876	4.887	251	1.400	3.487	107.399
4/27	3,762	847	3.186	141	0.530	2.656	110.055
4/29	2,222	820	1.822	223	0.496	1.326	111.381
5/1	2,702	804	2.172	301	0.813	1.359	112.740
5/4	4,364	812	3.544	350	1.527	2.017	114.757
5/6	2,842	848	2.410	400	1.137	2.010	116.767

APPENDIX E-3

DIMP REMOVAL BY CALGON SERVICE CARBON

DATE	FLOW l	INITIAL CONCEN. AVG. µg/l	g IN	FINAL CONCEN. µg/l	g OUT	GRAMS REMOVED INCREMENTAL	GRAMS REMOVED CUMULATIVE
1/16	1,170	813	0.951	<10	0	0.951	0.951
2/11	37,880	933	35.342	<10	0	35.342	36.293
2/17	8,706	743	6.469	<10	0	6.469	42.762
2/20	2,782	760	2.114	<10	0	2.114	44.876
2/23	5,038	818	4.121	16.3	0.082	4.039	48.915
2/25	2,778	804	2.234	44.5	0.124	2.11	51.025
2/27	2,714	851	2.310	21.4	0.058	2.252	53.277
3/2	3,107	968	3.008	32	0.099	2.909	56.186
3/9	9,027	869	7.844	84.9	0.766	7.078	63.264
3/11	3,327	809	2.692	263	0.875	1.817	65.081
3/13	2,831	818	2.316	259	0.733	1.583	66.664
3/17	3,020	804	2.428	254	0.767	1.715	68.379
3/20	4,357	824	3.590	364	1.586	2.004	70.383
3/23	3,005	854	2.566	297	0.892	1.674	72.057
3/25	3,028	856	2.592	392	1.187	1.405	73.462
3/27	2,835	869	2.464	457	1.296	1.168	74.63
3/30	3,391	837	2.838	433	1.468	1.37	76.0
4/1	3,009	813	2.446	620	1.866	0.58	76.58
4/3	2,998	814	2.440	821	2.461	0.0	76.58
4/6	3,955	849	3.358	811	3.208	0.15	76.73
4/8	2,941	887	2.609	839	2.467	0.142	76.872